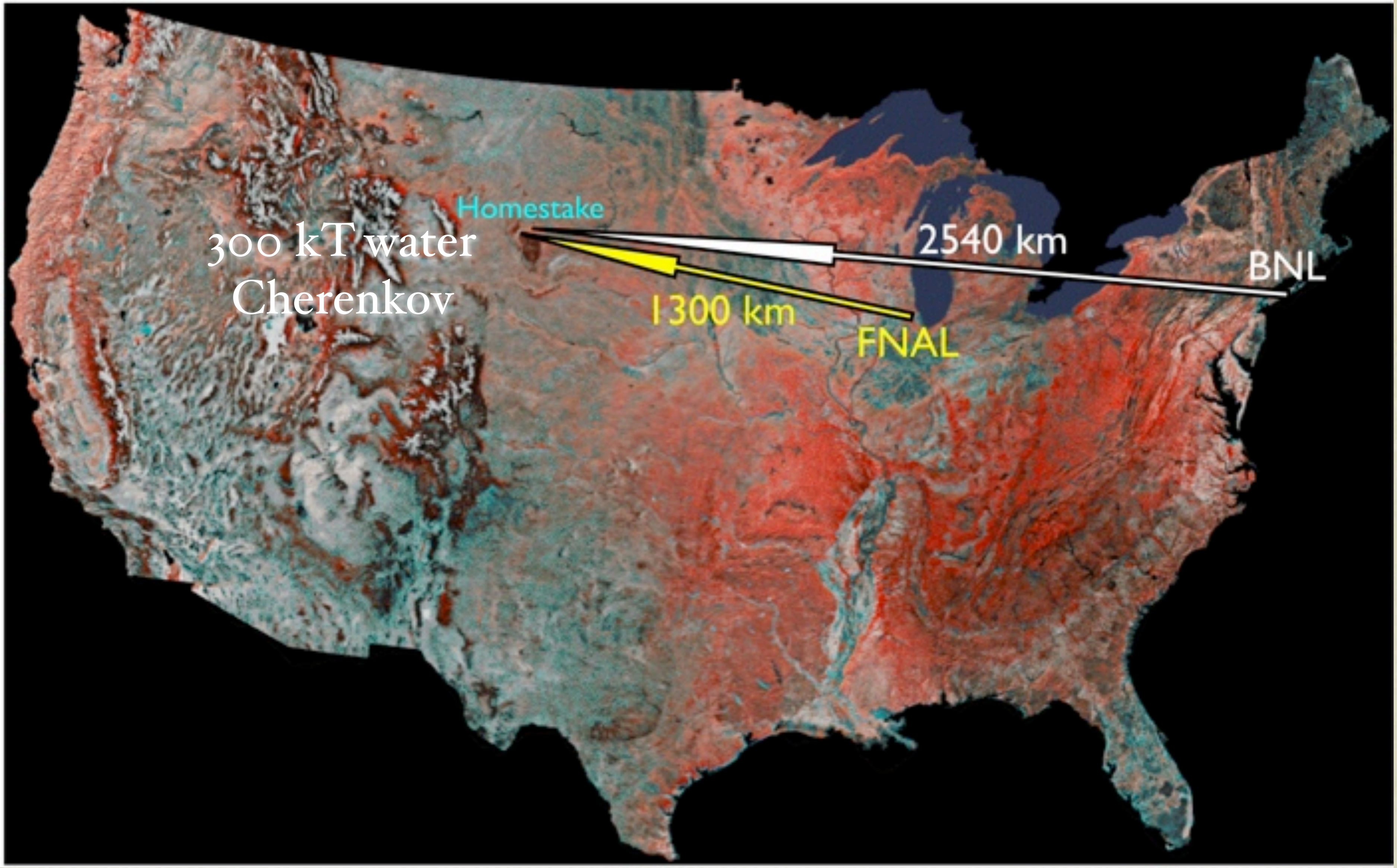
FNAL to DUSEL long baseline experiment

- Milind Diwan (BNL, USA) 12/20/2008 Mayly's workshop



Various Event Rates

Physics	Rate/100kT/yr	Energy Range
1 MW, 120 GeV FNAL Beam	~30000	0.5-10 GeV
Proton decay	1	1 GeV
Atmospheric nu	14000	1-100 GeV
Solar nu_e	45000	>5 MeV
Supernova at 10kpc	23000	>5 MeV
Relic Supernova	30	15-25 MeV

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Cosmic Muons

Depth (mwe)	Rate (Hz)	Spallation (Hz)
0	500 kHz	8.5 kHz
265	3 kHz	50 Hz
880	400 Hz	7 Hz
2300	5 Hz	0.1Hz
2960	1.3 Hz	0.022Hz
3490	0.6 Hz	0.010 Hz
3620	0.26 Hz	0.0044 Hz
4290	0.09 Hz	0.002 Hz

Uncorrelated rate ~ few hundred/day

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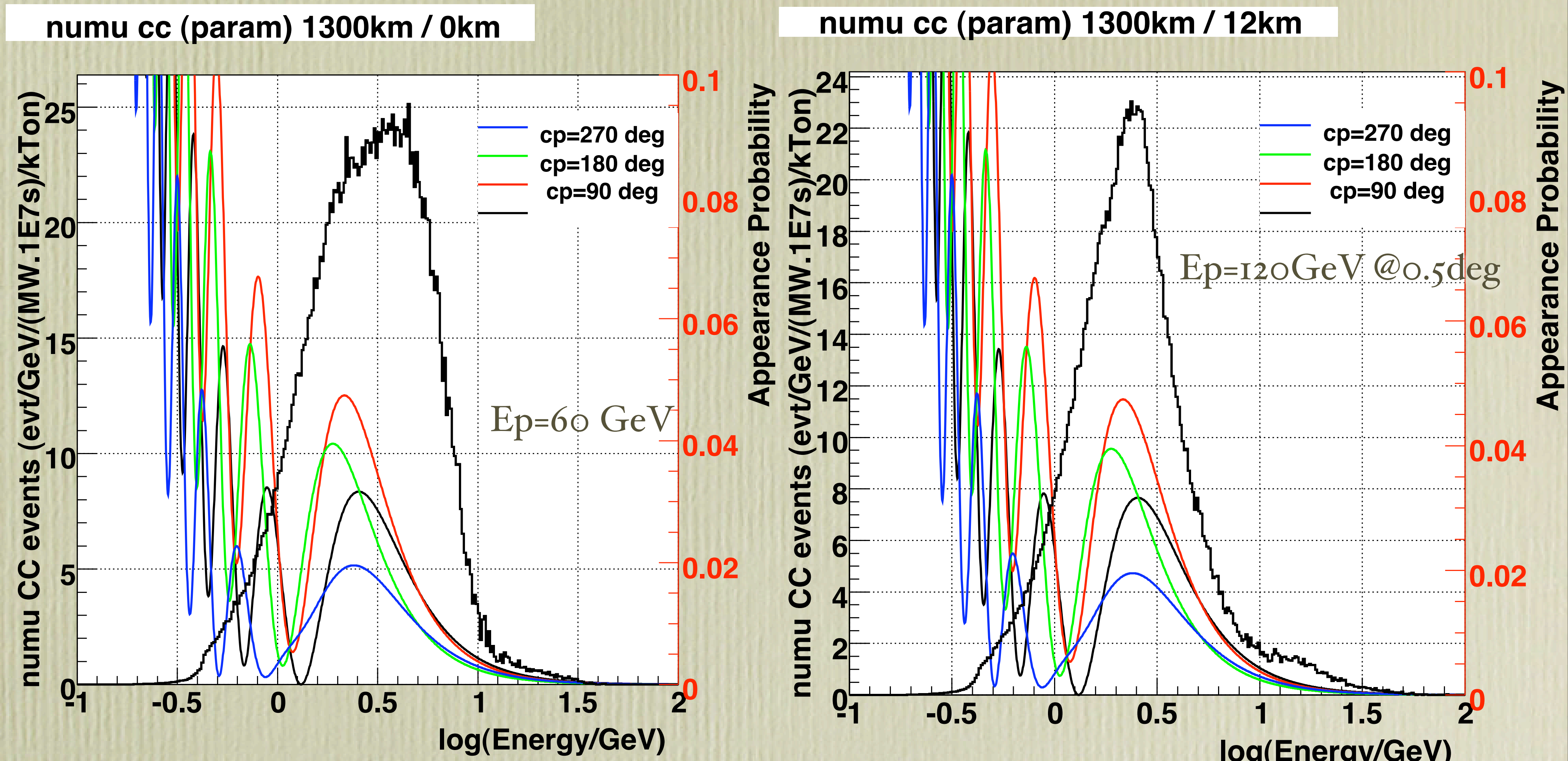
Spectra FNAL to DUSEL (WBLE:wide band low energy)



- 60 GeV at 0deg: CCrate: 14 per (kT*10^20 POT)
- 120 GeV at 0.5deg:CCrate: 17 per(kT*10^20POT)

Work of M. Bishai and B. Viren using NuMI simulation tools

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Key Event Rate in 100kT*MW*10^7

5.2e20 POT @ 120 GeV

$$\nu_\mu \longrightarrow \nu_e$$

$\Delta m^2_{21,31} = 8.6 \times 10^{-5}, 2.5 \times 10^{-3} eV^2$ $\sin^2 2\theta_{12,23} = 0.86, 1.0$ $\sin^2 2\theta_{13} = 0.02$

δ_{CP}

	$sgn(\Delta m^2_{31})$	0 deg	+90 deg	180 deg	-90 deg	nue backg
WBLE NU (1300km)	+	87	48	95	134	47
WBLE NU (1300km)	-	39	19	51	72	
WBLE ANU (1300km)	+	20	27	15	7.2	17
WBLE ANU (1300km)	-	38	52	33	19	

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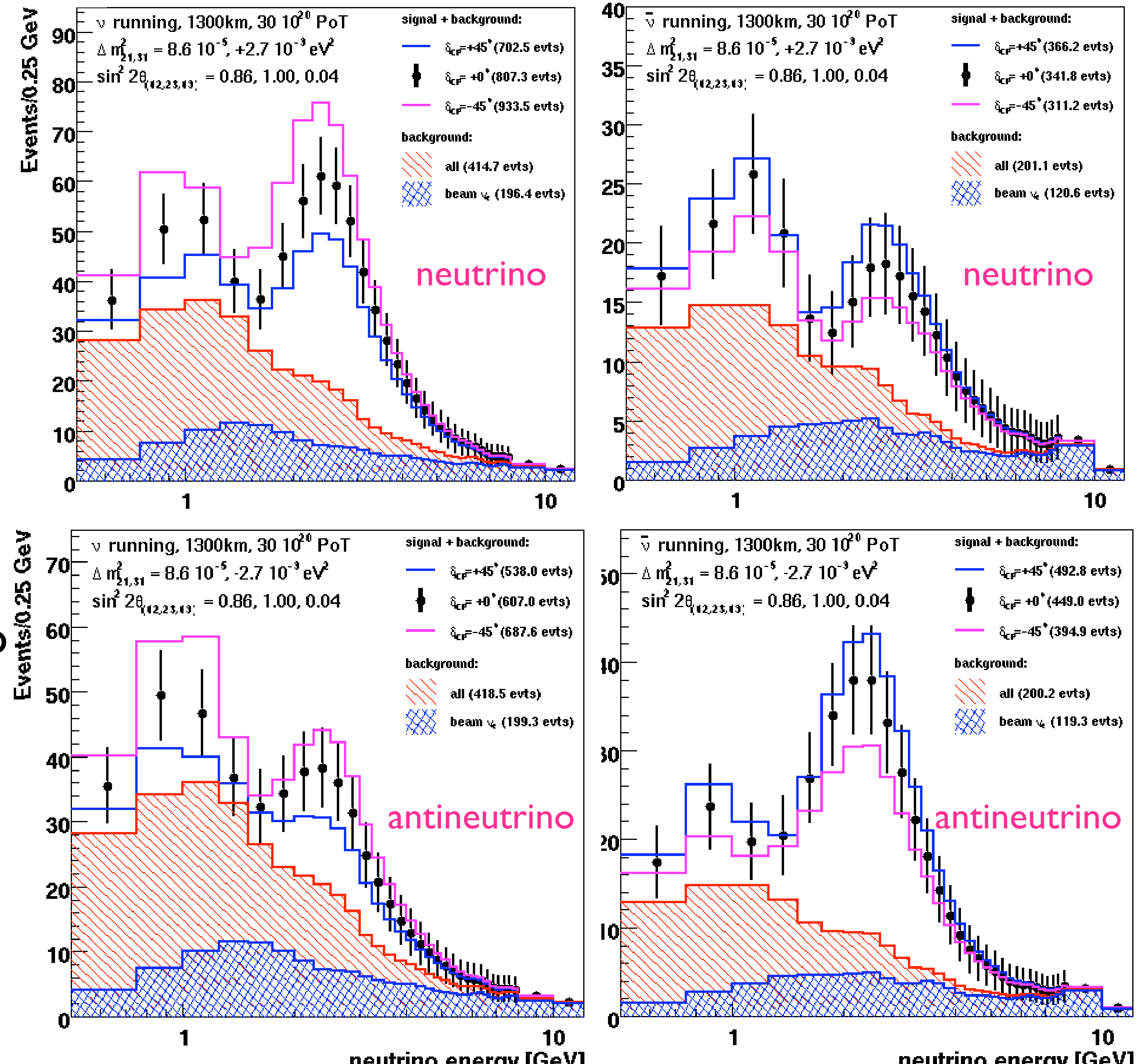
Electron neutrino appearance spectra

$\sin^2 2\theta_{13} = 0.04$, 300kT WCe. , WBLE 120 GeV, 1300km, 30E20 POT.

$(-\delta_{cp} = -45^\circ, -\delta_{cp} = +45^\circ)$

- All background sources are included.
- S/B ~ 2 in peak.
- NC background about same as beam nue backg.
- For normal hierarchy sensitivity will be from neutrino running.
- For reversed hierarchy anti-neutrino running essential.
- Better efficiency at low energies expected with higher PMT counts.

Normal Reversed

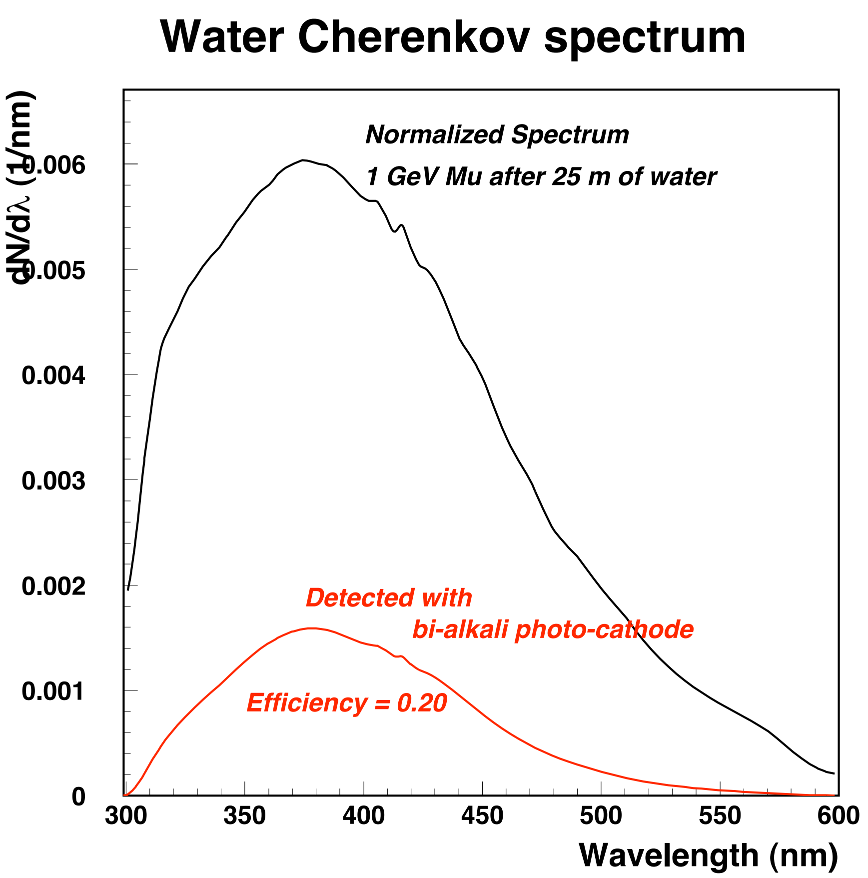


Amount of signal

5 MeV = 25 p.e.

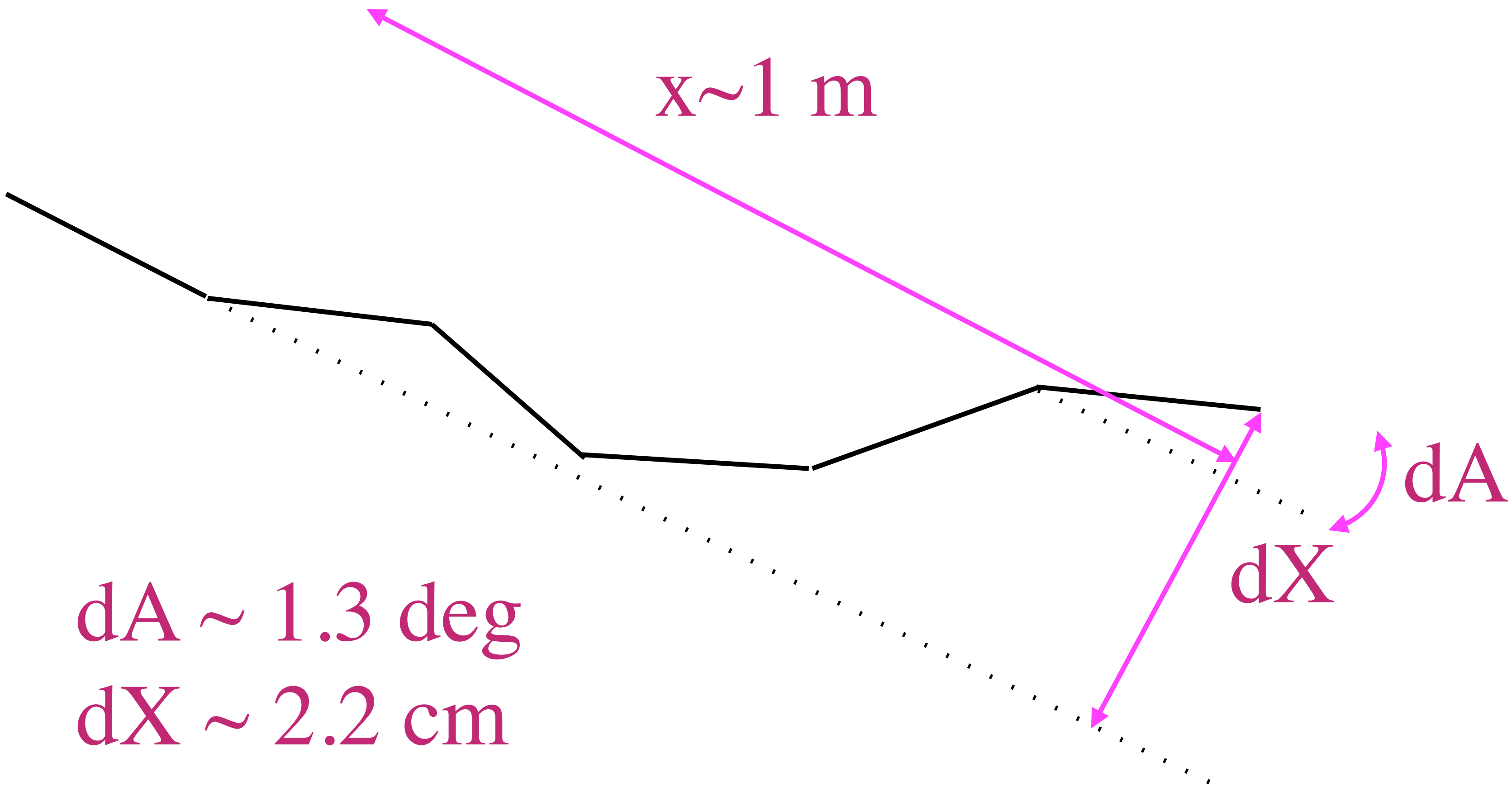
for 25% coverage with 20 % Q.E.

Gammas, Showers fluctuate due to electrons below threshold



n= 1.35 1.34 1.33

Muon Pattern

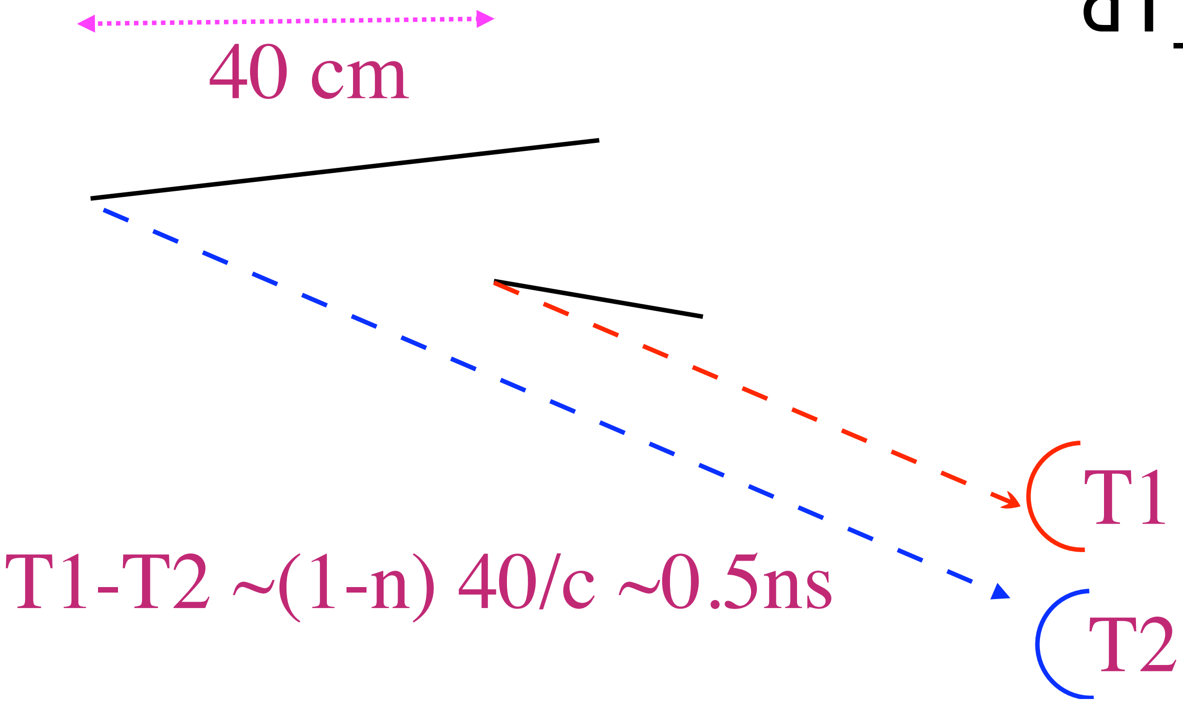


Multiple scattering limit is ~1-2 deg.

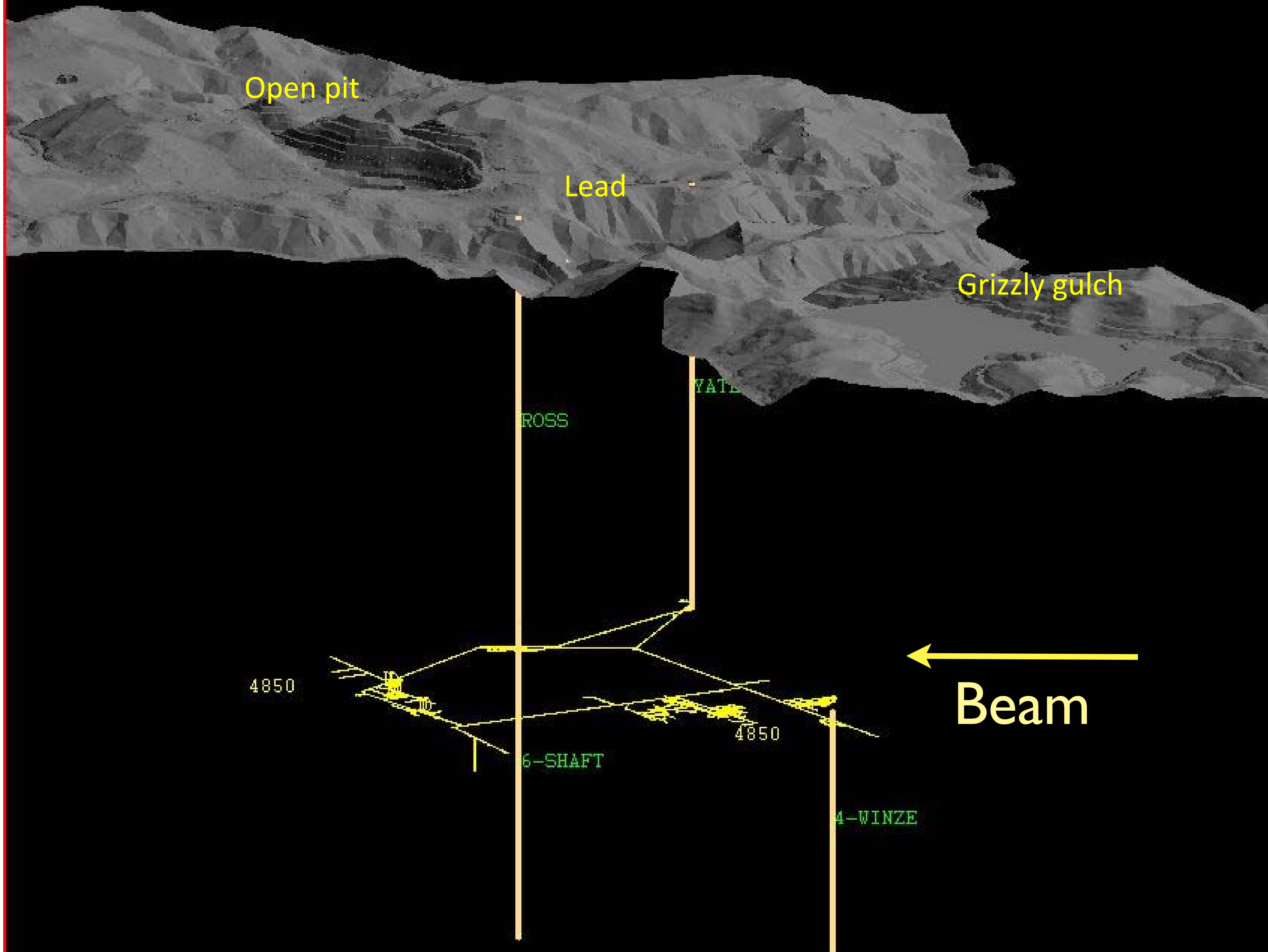
For average light path length of 25 m =>
~50 cm spacing between tubes is sufficient.

Timing requirement

dT_dispersion ~ 3 ns
(over 50 m)



- Need to separate showers. Shown to work statistically, but can be improved.



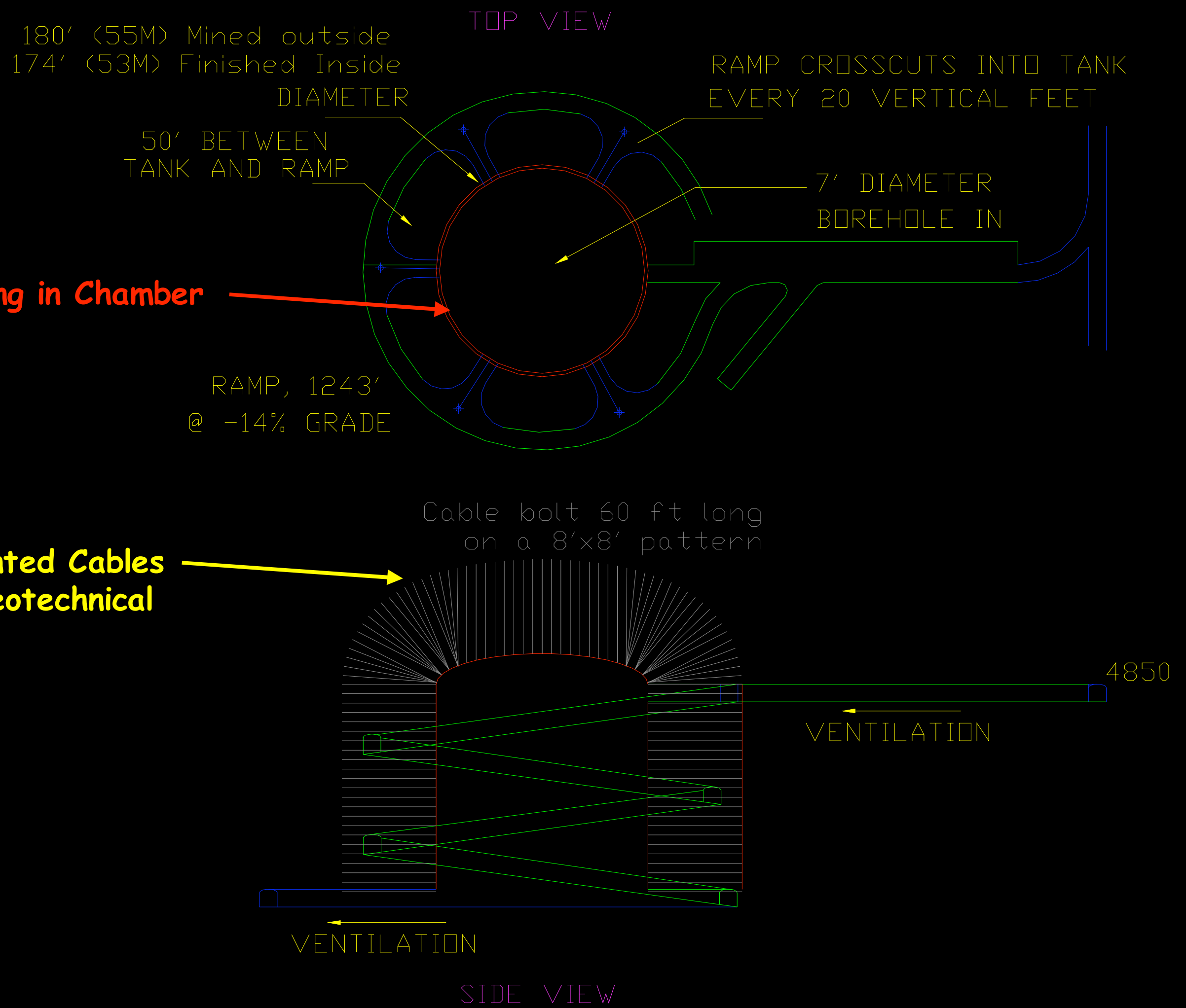
The Detector @ homestake

Megaton Modular Multi-Purpose Neutrino Detector

✓ Chamber Design

Controlled Blasting in Chamber

Could use Instrumented Cables for Engineering / Geotechnical Study



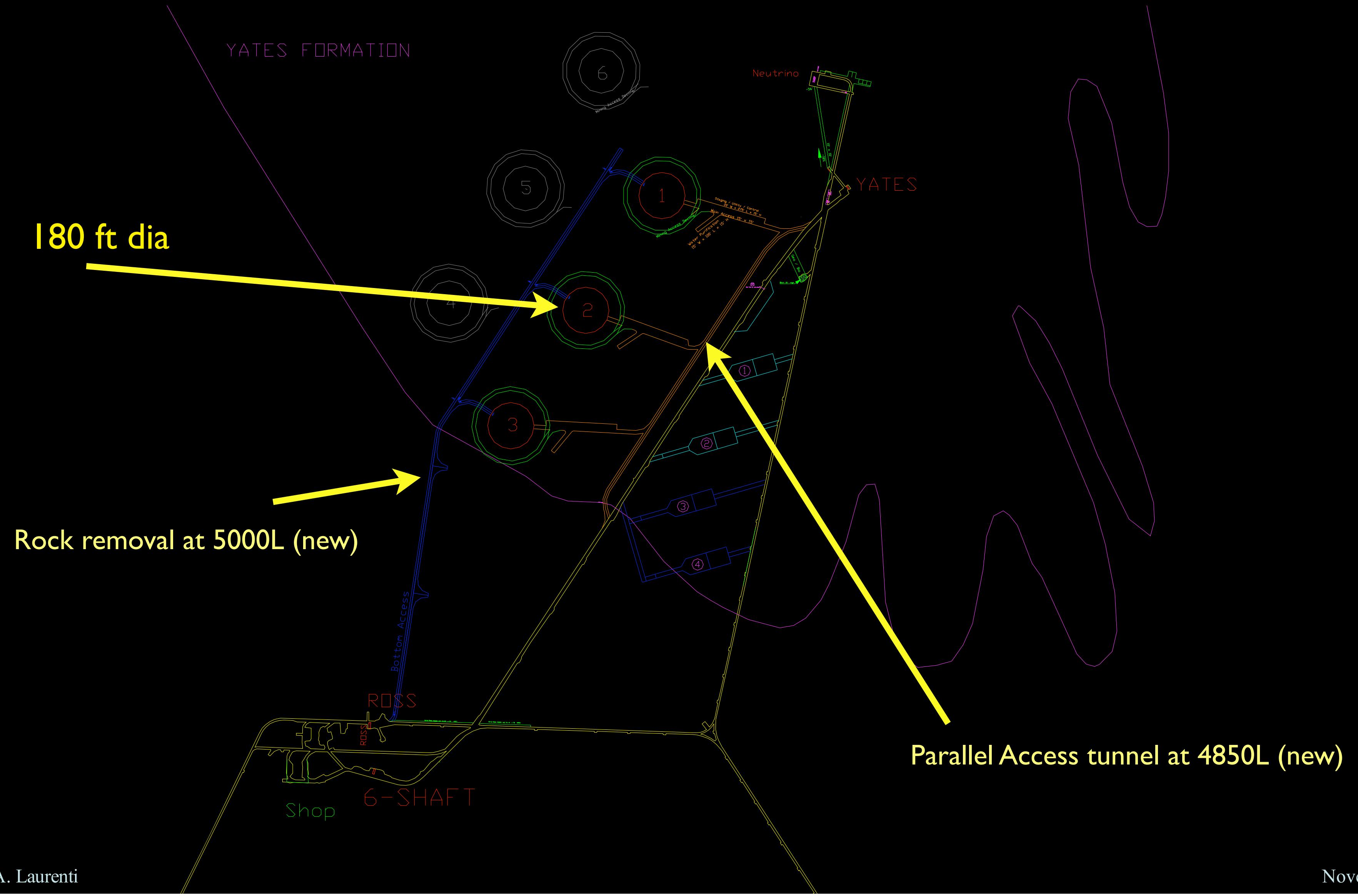
Mark A. Laurenti (Former Homestake Chief engineer)

November 2007

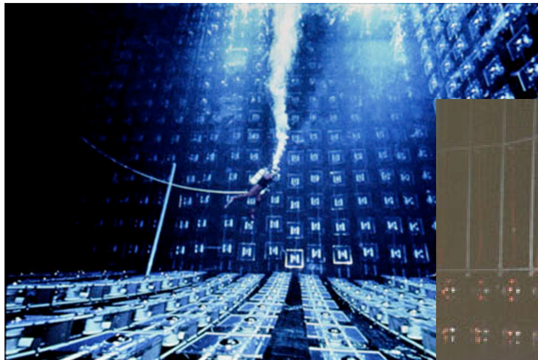
Megaton Modular Multi-Purpose Neutrino Detector

✓ Modular Configuration

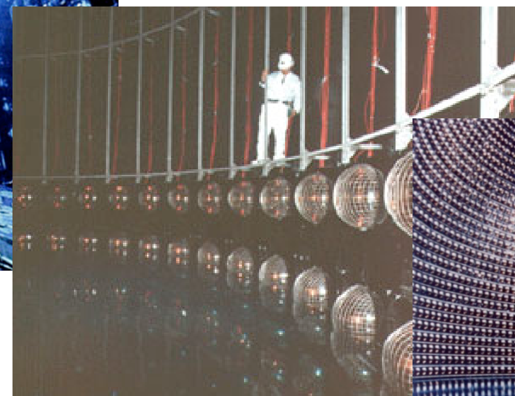
muon rate/cavern 0.1-0.3 Hz



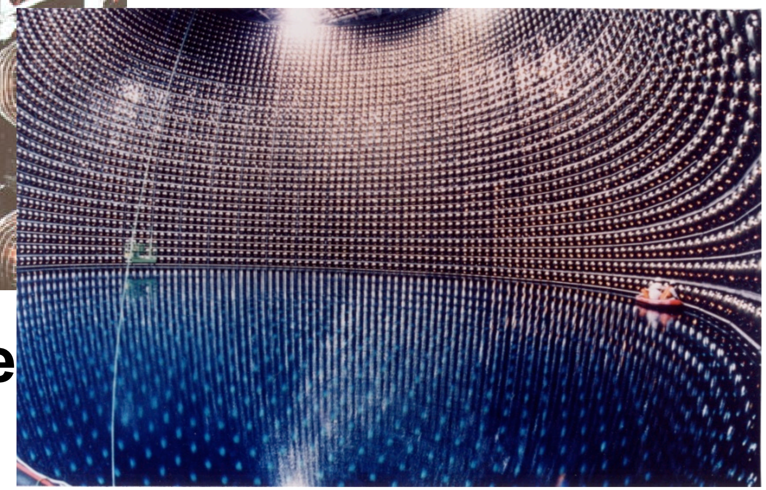
Water Cherenkov Detector



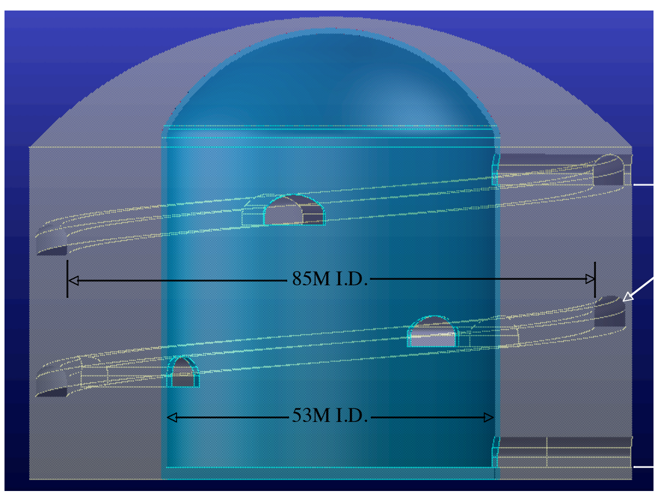
IMB
3 ktons



Kamiokande
1 kton



Super-Kamiokande
22 ktons

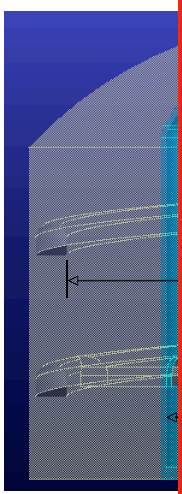


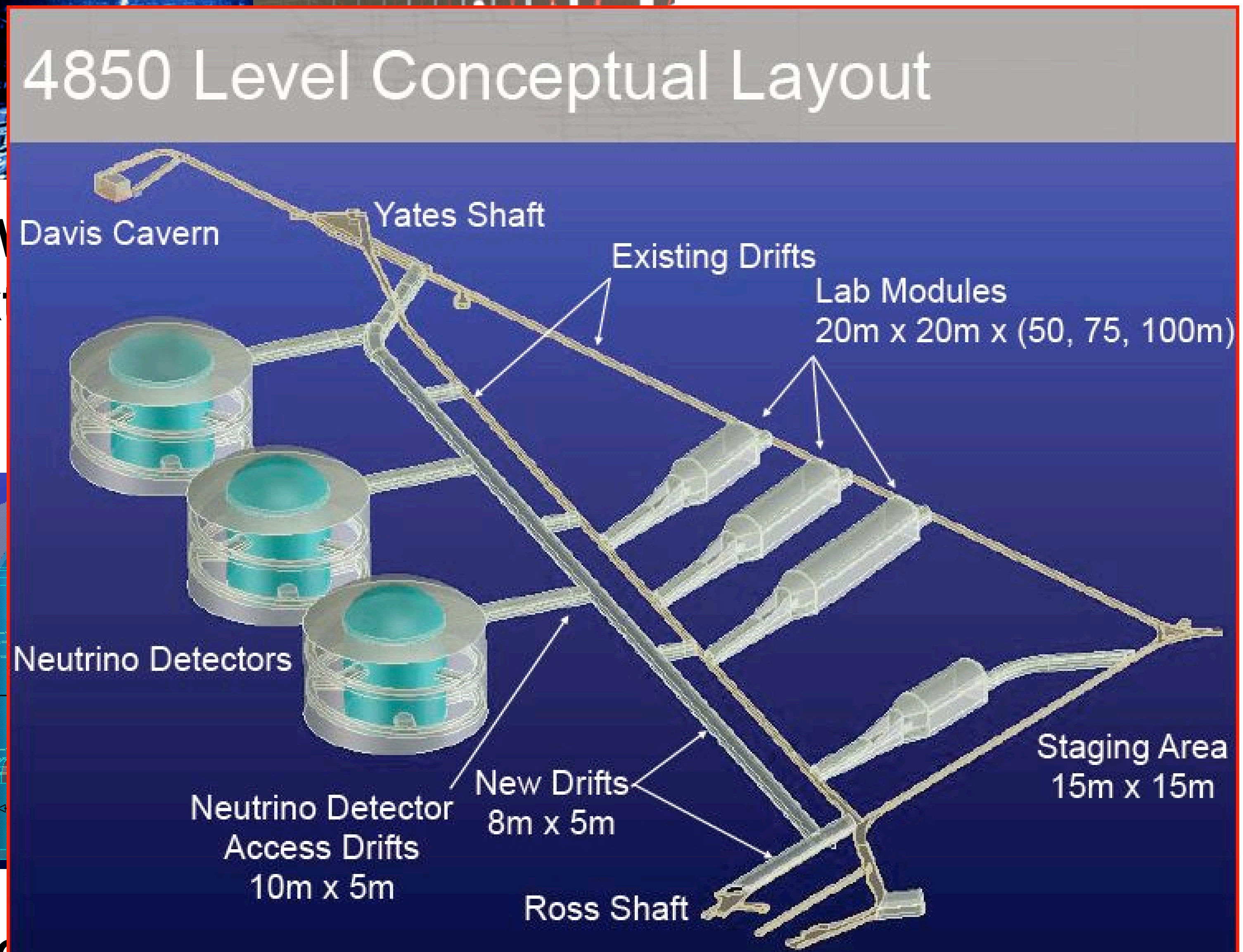
1 module fid:100 kT

300 kT

Water Cherenkov Detector

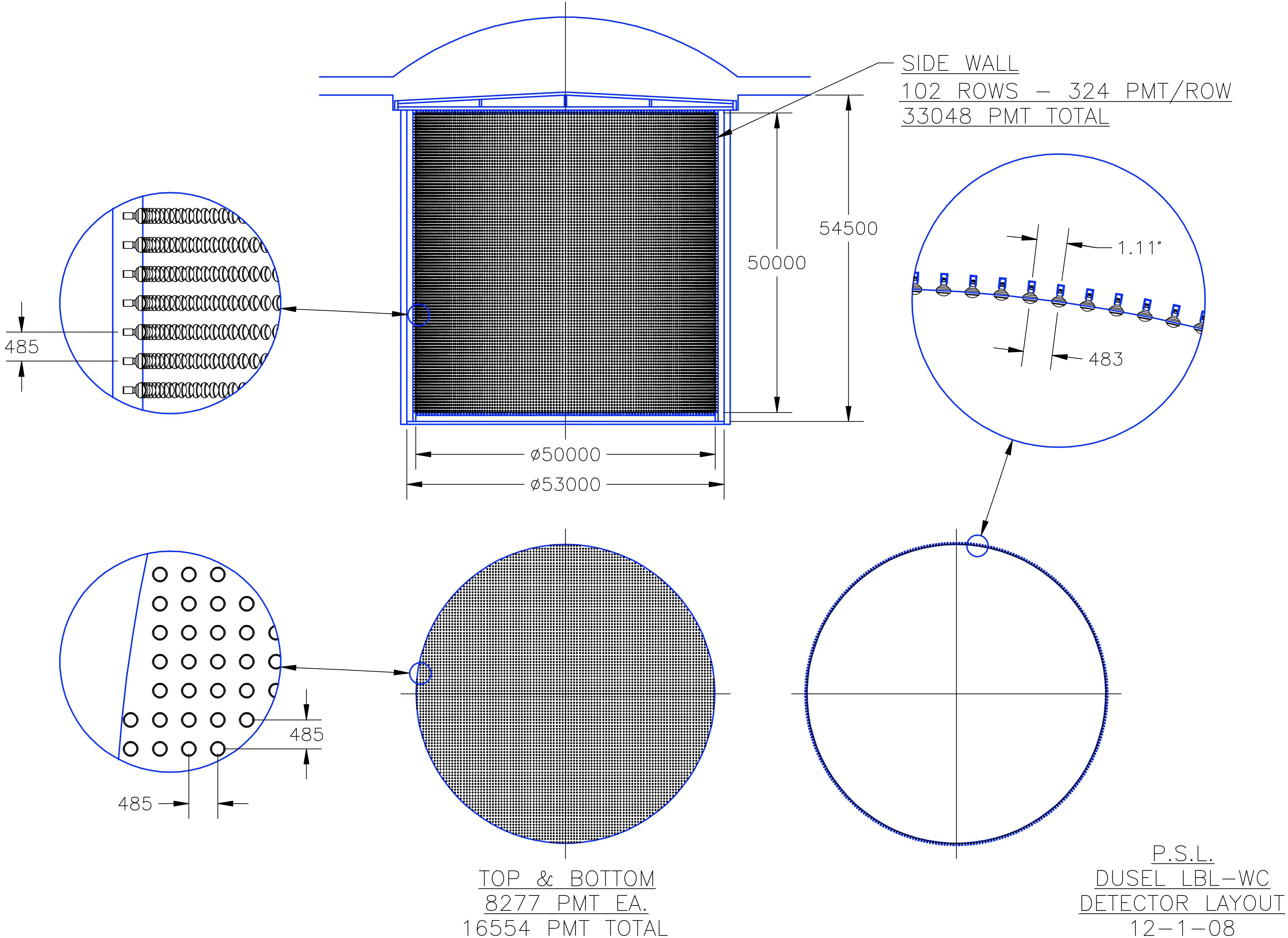
IM
3 k





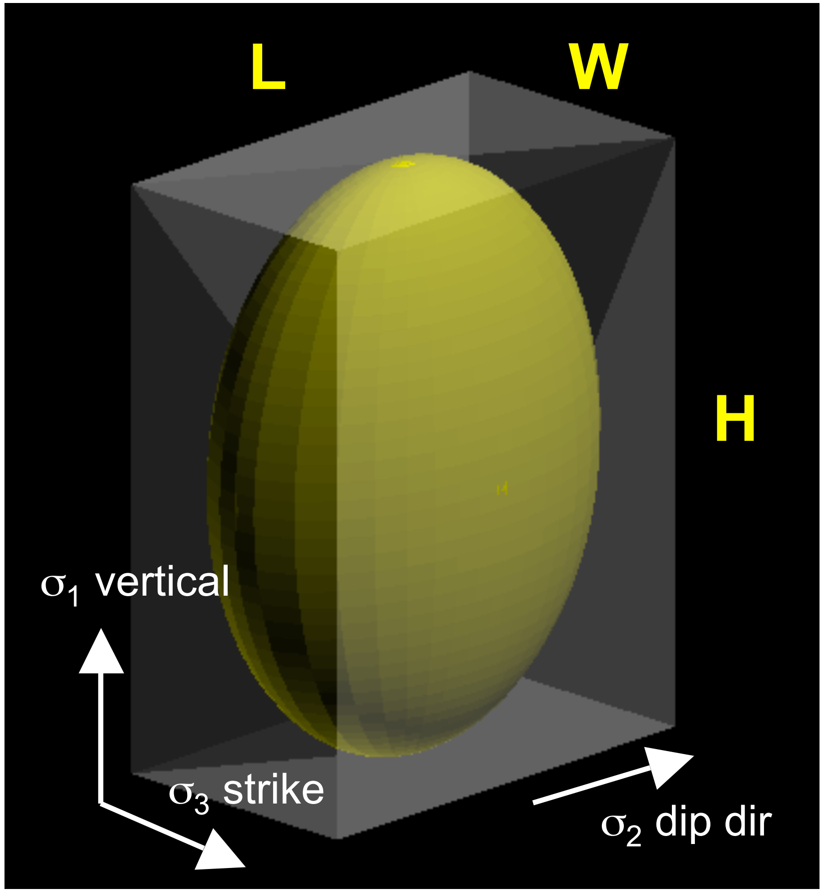
1 mod

300 kT

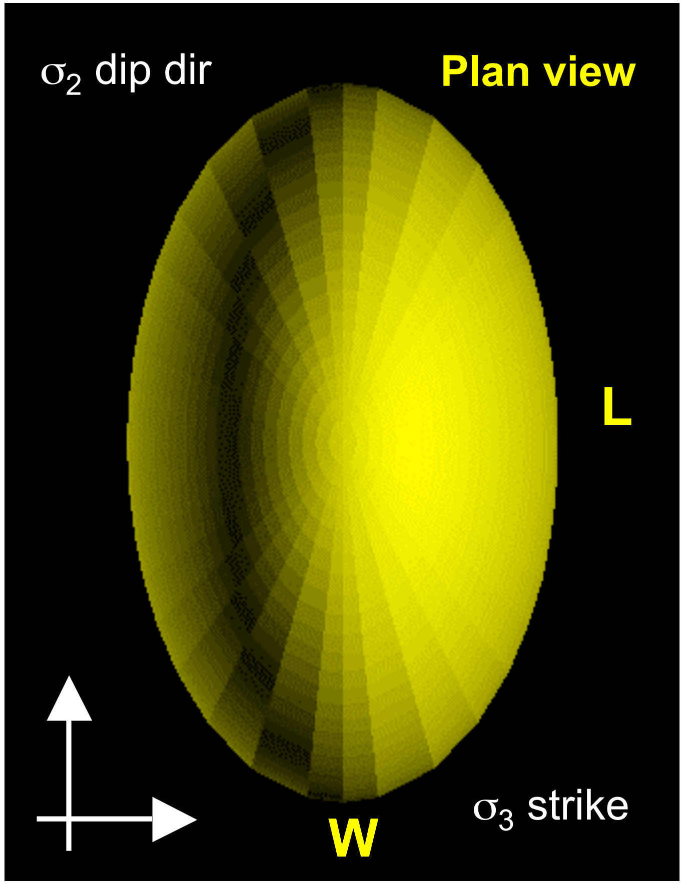


SIDE WALL
102 ROWS - 324 PMT/ROW
33048 PMT TOTAL
54500
50000
485
1.11°
483
ø50000
ø53000
485
485
TOP & BOTTOM
8277 PMT EA.
16554 PMT TOTAL
P.S.L.
DUSEL LBL-WC
DETECTOR LAYOUT
12-1-08

The best shape and the most favorable orientation:



$\sigma_1 > \sigma_2 > \sigma_3$ = H>L>W = a>b>c

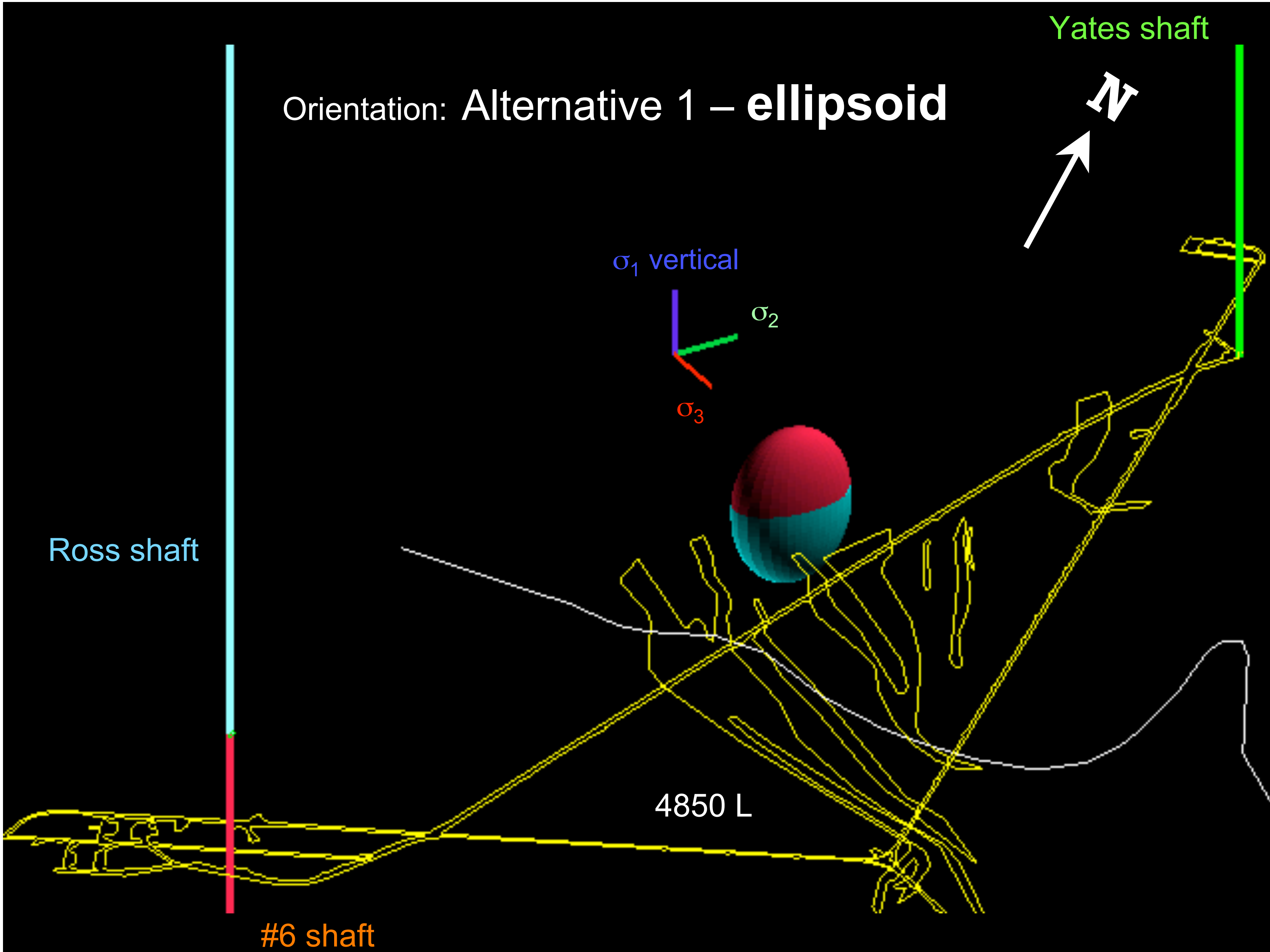


ELLIPSOID

H>L>W

L/W = 1.67

Hladysz



Orientation: Alternative 1 – ellipsoid
Yates shaft
N
σ_1 vertical
σ_2
σ_3
Ross shaft
4850 L
#6 shaft

Hladysz

PMT R&D

- Issues are: making 150000 tubes in 6 years time, their efficiency, and their pressure performance.
- If PMTs can stand higher pressure, the cavern can be taller => more fiducial volume.
- Have had meetings with Photonis and Hamamatsu: no barrier to PMT production except money.

PMT considerations

	10 inch R7081	20 inch R3600
Number (25% cov)	~50000	~14000
QE	25%	20%
CE	~80%	~70%
rise time	4 ns	10 ns
Tube length	30 cm	68 cm
Weight	1150 gm	8000 gm
Vol.	~5 lt	~50 lt
pressure rating	0.7Mpa	0.6Mpa
∢ coverage/pmt	0.6 deg	1.1 deg
∢granularity	1.0 deg	2.1 deg

PMT: further choice

Items	Example 12-inch PMT	R7081 10-inch PMT	R5912 8-inch PMT
Diameter	300 mm	253 mm	202 mm
Effective Area	280 mm min.	220 mm min.	190 mm min.
Tube Length	330 mm	245 mm	220 mm
Dynodes	LF/10-stage	LF/10-stage	LF/10-stage
Applied Voltage	1500 V	1500 V	1500 V
GAIN	1.00E+07	1.00E+07	1.00E+07
T.T.S.(FWHM)	2.8 ns	2.9 ns	2.4 ns
P/V Ratio	2.5	2.5	2.5
Dark Counts	10,000 cps	7,000 cps	4,000 cps

NEW !

HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

Developmental Plan for 12 inch PMT

Date : August 6, 2008

2008		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	2009 JAN	FEB
PMT Design	Simulation Electron Trajectory	Basic Design		Feedback Check											
	Electrode Design			Practical Design											
Material Preparation								Glass Bulbs				Initial conditioning is done during this period.			
								Electrodes							
								Insulating Plates							
Production for Prototypes															
Inspection														Various Tests	
Delivery															Sample Tubes

Some sample tubes would be available in FEB. 2009.

We need 6 months for preparation of mass-production version.

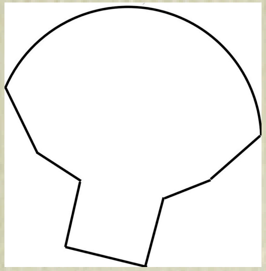
HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

Tube production

Glass

Stamped metal and wire parts

First assembly
vacuum deposition of metal platings
Graded seal

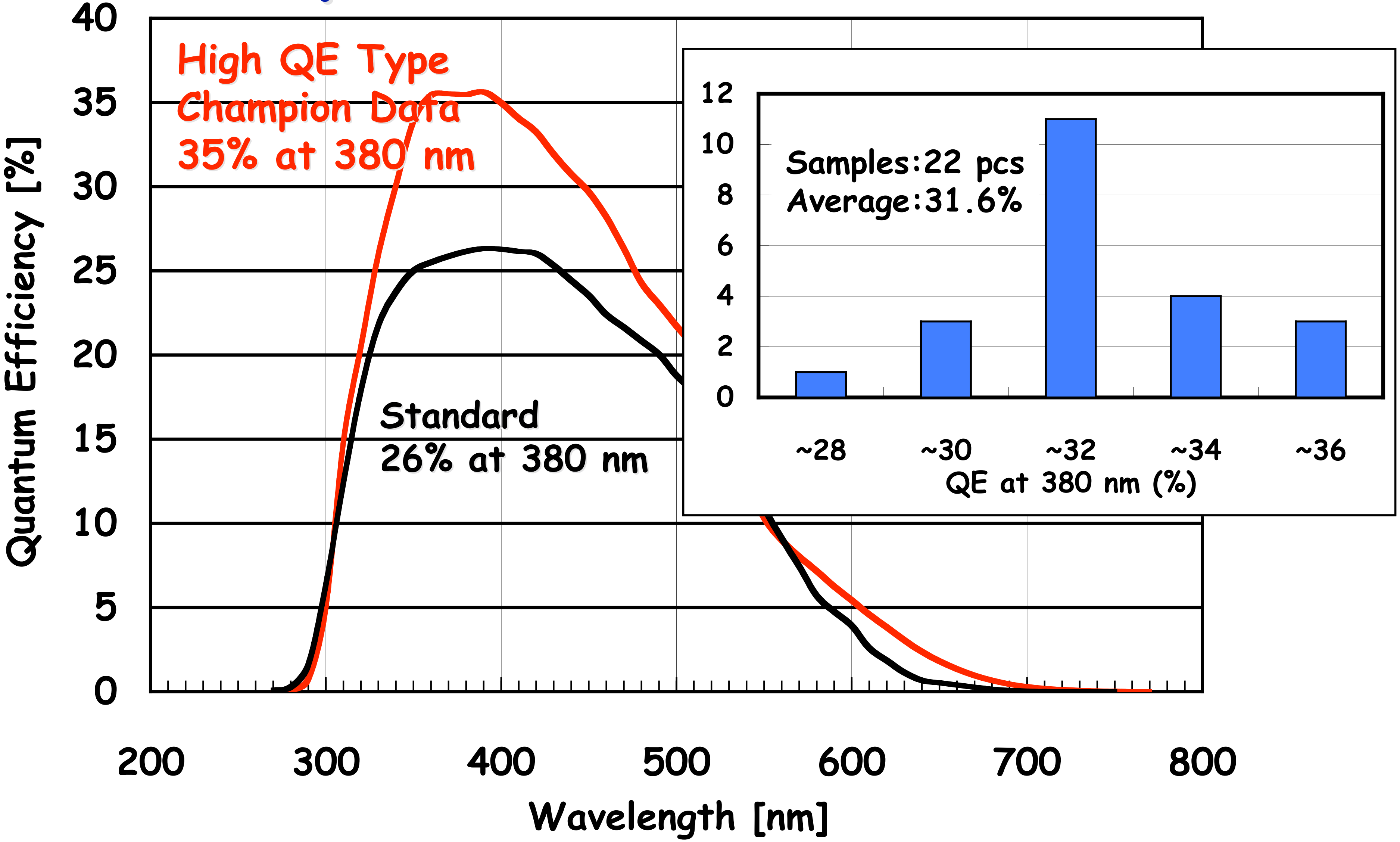


Final vacuum
Cathode deposition

Final assembly of 10 inch tubes needs lab space of 30’x30’; six stations with 6 pmts/station; 1 full day => 36tubes/day = icecube production.
tripling this rate is not difficult

HPK and Photonis are NOT concerned about their ability to manufacture at this rate

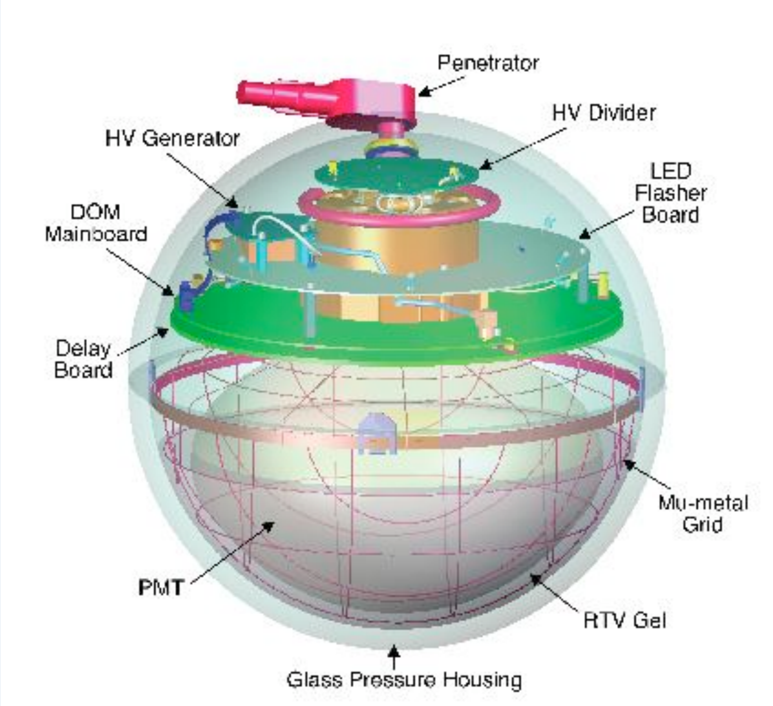
Example data R7081 (10 inch)



Goal of development is 43%

78 high quantum efficiency 10"PMT successfully tested for use in IceCube

- More than 4000 sensors with standard 10" PMT (R7081-02) integrated and tested in IceCube
- 78 high quantum efficiency PMT (10") tested with IceCube standard production test program.
- Result:
  - Quantum efficiency ~38% higher (405 nm, -40C)
  - No problems found
  - Low temperature (-40C) noise behavior scales with quantum efficiency as expected.
- Plan to use high QE PMT on 6 Deep Core strings for enhanced sensitivity at low energies (<100GeV, dark matter)
- Sensors already at the South Pole



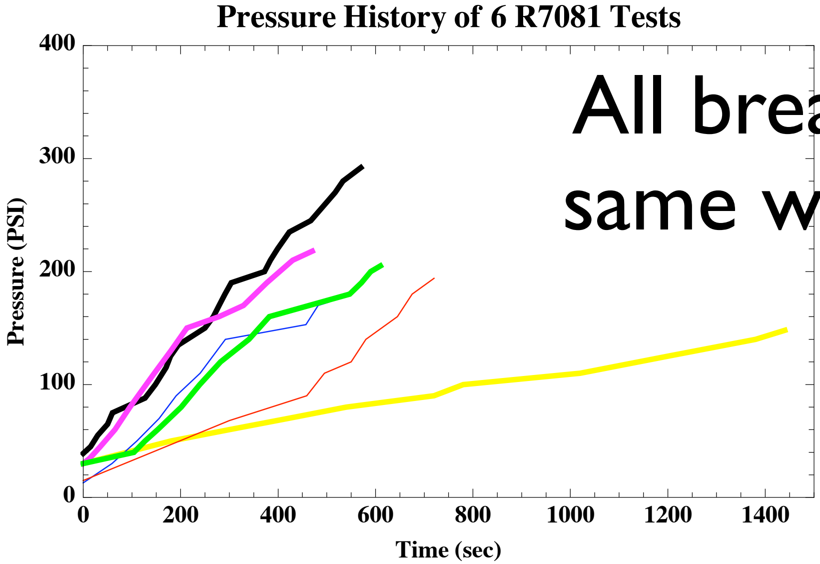
A. Karle, UW-Madison

Baseline Plan

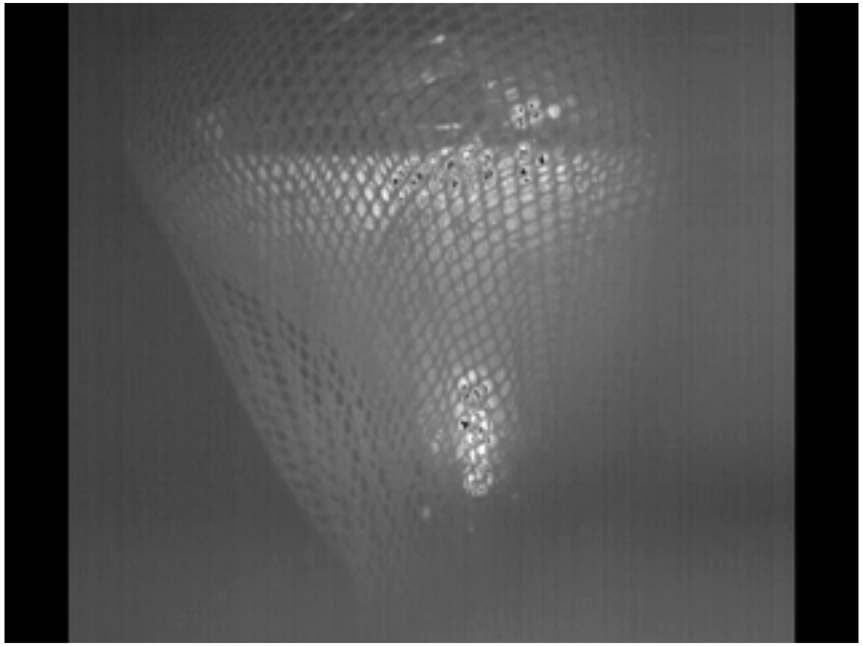
- The Baseline plan is R7081 with 25%cov*25%QE(Learned recently that high QE can be made at same rate).
- The correct number to look at is Coverage*QE*Collection eff.
- We will need 50000 to 70000 per chamber depending on shape to obtain similar amount of light collection as SK.
- R7081 has been used by Icecube. There is also production for other projects.
- Only issue for us is pressure performance.

What kind of information ?

- Pressure at implosion
- Implosion process. (fast motion movie), photos
- Pressure pulse



All break same way



Breakage at pins

What kind of information ?

- Pressure at implosion
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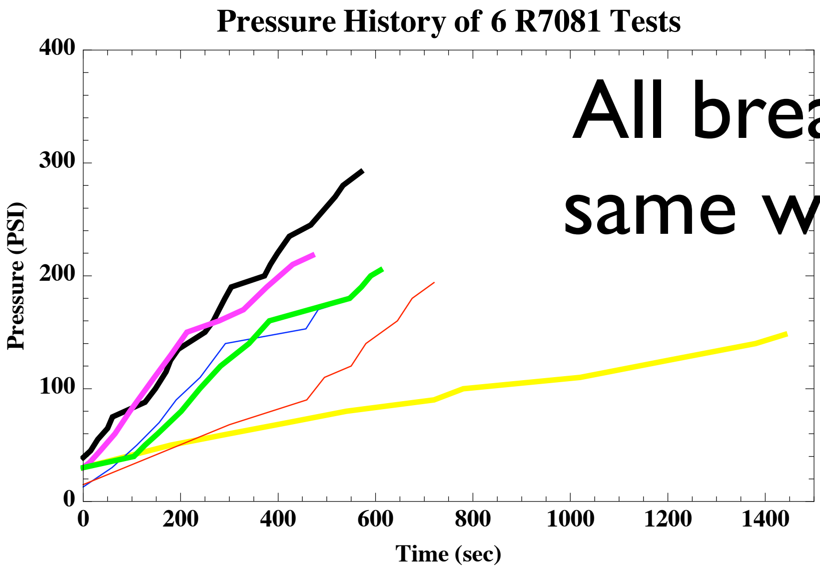
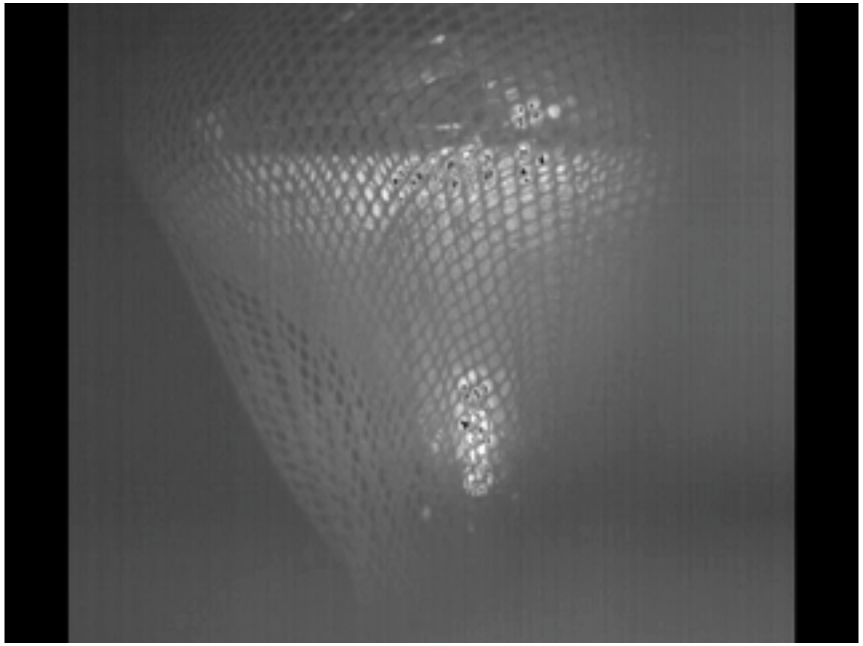


All break same way



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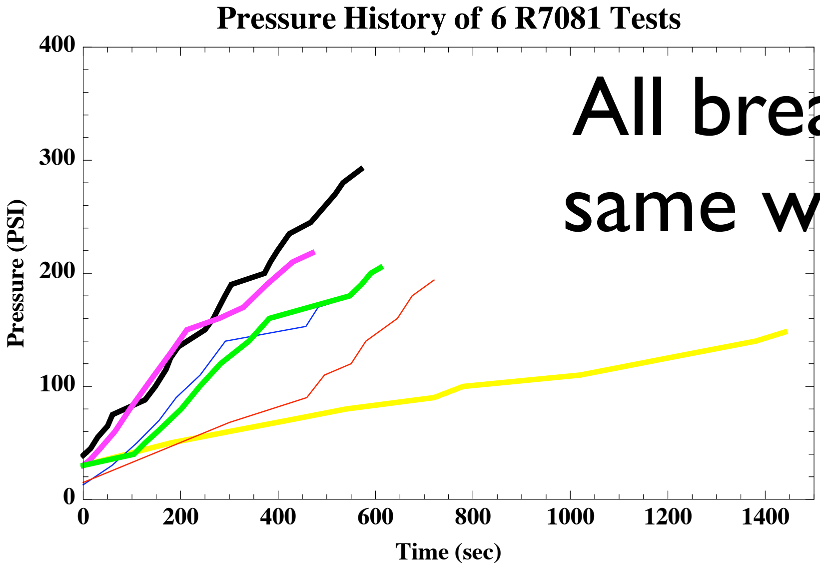
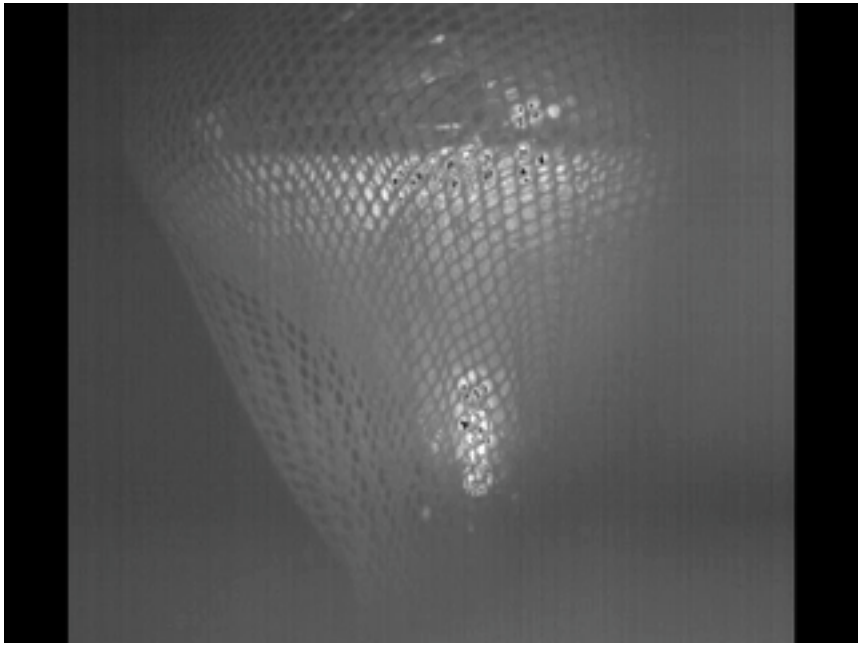


All break same way



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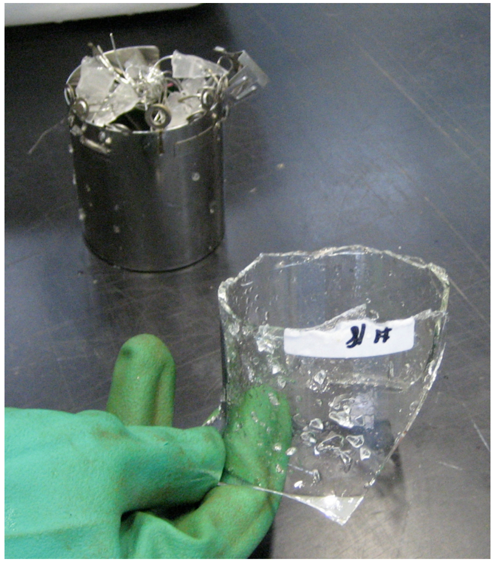
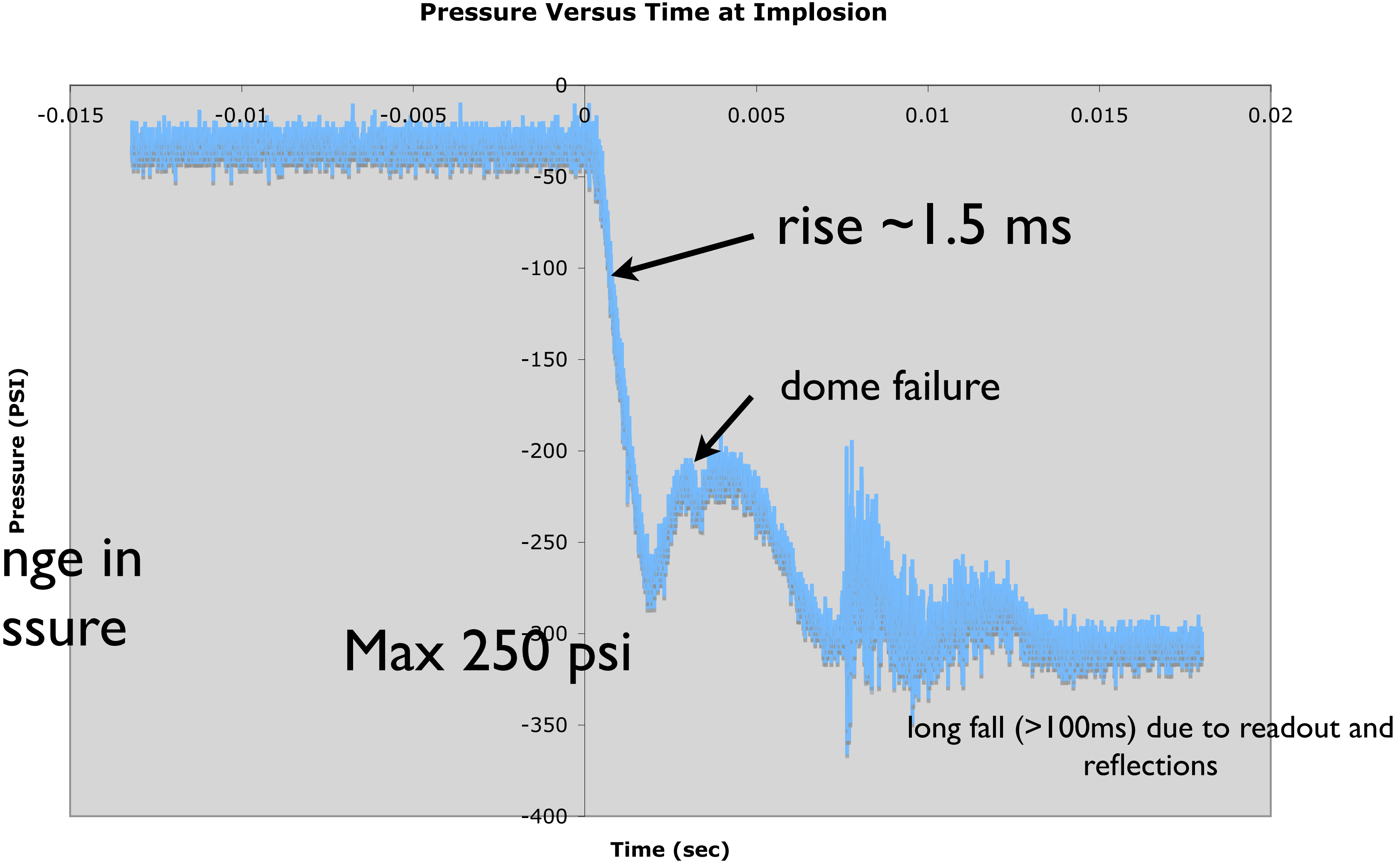


Typical R7081 (ta3085 at 13.4 bar (194 psi))

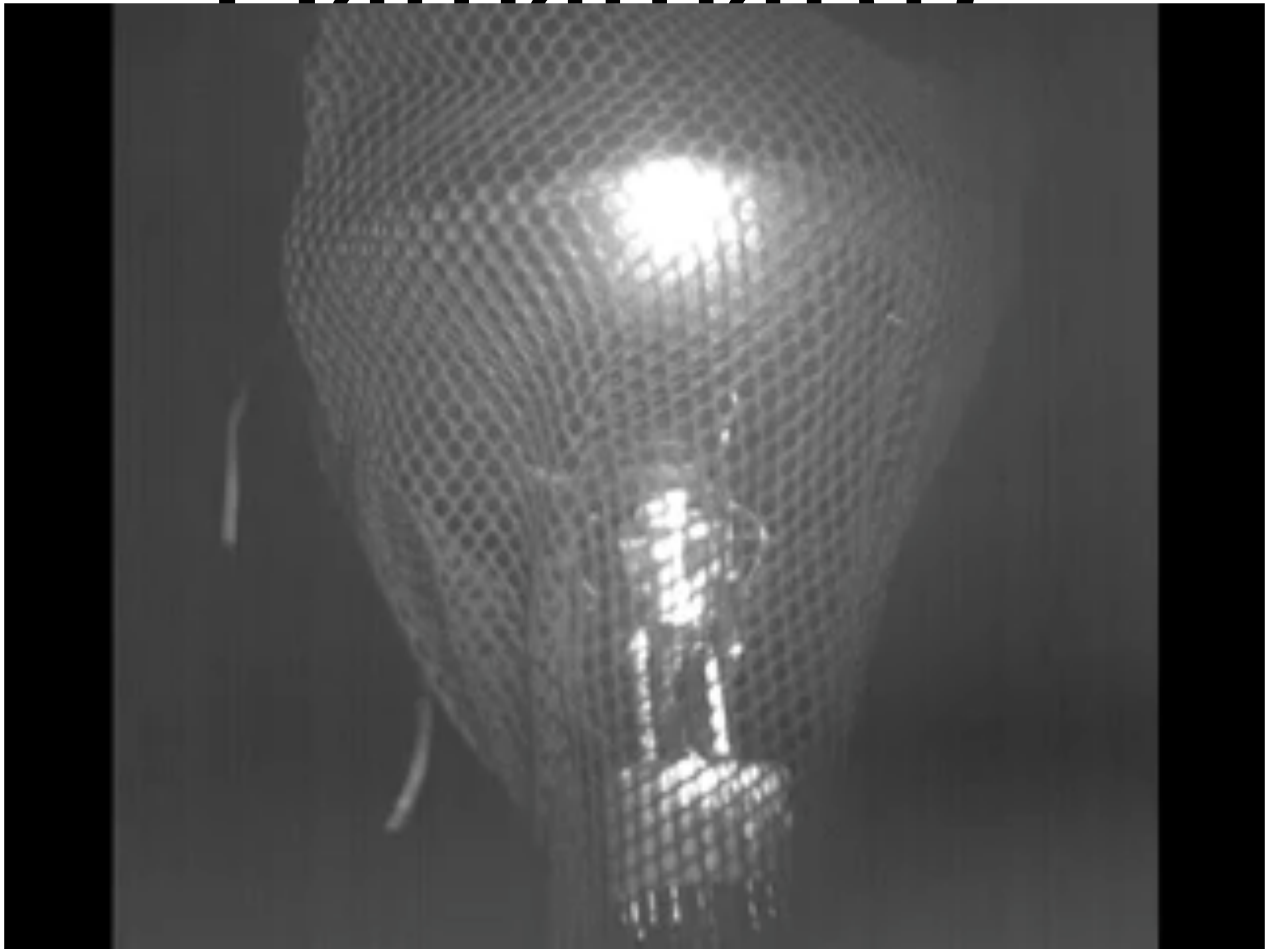


Change in Pressure

sensor at 40 inch

No shock wave because tank too small

another example (not Hamamatu)



Organization

- The beam and the water Cherenkov detector are an exercise in organization and planning.
- There have been 10 meetings of an interim executive board (more about this later)
- Two documents have been commissioned. (Depth paper and white paper)
- There have been several meetings at FNAL and Lead http://nwg.phy.bnl.gov/DDRD/cgi-bin/private/ListAllMeetings
- There is an Institutional Board.

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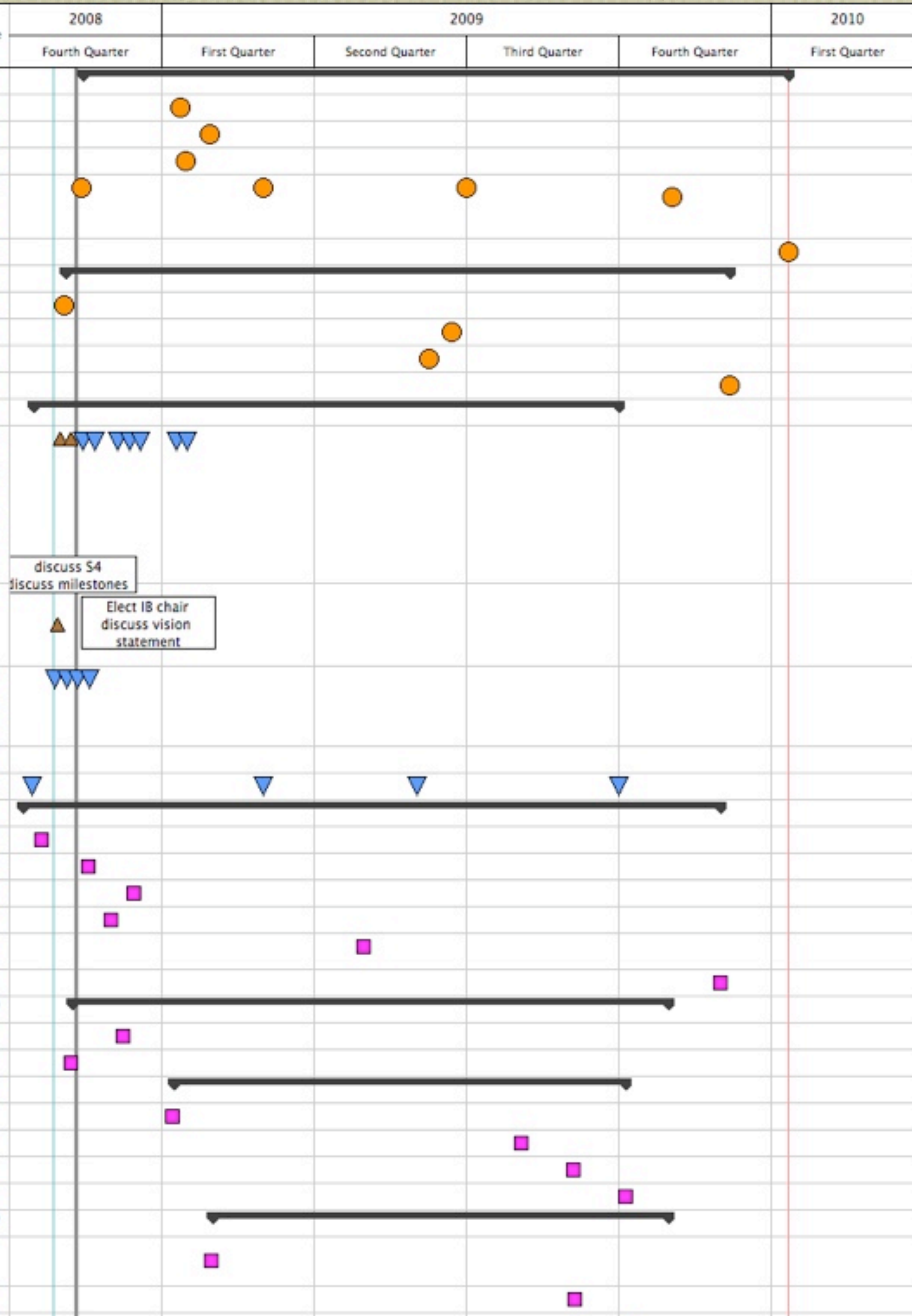
Funds

- P5 report and associated reports from various panels (NuSAG, NSF DUSEL selection panel, and others) very important.
- Initial guidance is CD0 in Dec. 2008 and CD1 in late 2009.
- This is to allow funds from DOE to flow.
- 4 avenues for funds: NSF regular, Sep 2008, DOE program money, NSF S4 money.

Activity Name	Duration (Work Days)	Start Date	Finish Date
External Reviews	**302.00**	**11/13/08**	**1/11/10**
CD0	0.00	1/12/09	1/12/09
NSF DUSEL facility	0.00	1/29/09	1/29/09
DOE presentation	0.00	1/15/09	1/15/09
HEPAP Meetings	0.00 0.00 0.00 0.00	11/13/08 3/2/09 7/1/09 11/2/09	11/13/08 3/2/09 7/1/09 11/2/09
CD1	0.00	1/11/10	1/11/10
Internal Reviews	**285.00**	**11/3/08**	**12/7/09**
FNAL PAC	0.00	11/3/08	11/3/08
BNL PAC	0.00	6/22/09	6/22/09
BNL Detector Management	0.00	6/8/09	6/8/09
BNL director's review	0.00	12/7/09	12/7/09
Collaboration Meetings	**252.00**	**10/14/08**	**10/1/09**
Executive Meetings	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	10/31/08 11/7/08 11/14/08 11/21/08 12/5/08 12/12/08 12/19/08 1/9/09 1/16/09	10/31/08 11/7/08 11/14/08 11/21/08 12/5/08 12/12/08 12/19/08 1/9/09 1/16/09
Institutional Board Meetings	0.00	10/30/08	10/30/08
Collaboration Geo-board	0.00 0.00 0.00 0.00	10/28/08 11/4/08 11/11/08 11/18/08	10/28/08 11/4/08 11/11/08 11/18/08
Technical Board			
Full Collaboration Meeting	0.00 0.00	10/14/08 3/2/09	10/14/08 3/2/09
Documents	**299.00**	**10/8/08**	**12/1/09**
Mission statement	0.00	10/20/08	10/20/08
Depth Paper	0.00	11/17/08	11/17/08
White paper	0.00	12/15/08	12/15/08
CD0 cost estimate	0.00	12/1/08	12/1/08
Physics Design Report /Proposal	0.00	4/30/09	4/30/09
Conceptual Desion Report	0.00	12/1/09	12/1/09
Geotechnical Documents	**256.00**	**11/7/08**	**10/30/09**
CD0 design and cost	0.00	12/8/08	12/8/08
Input to the depth	0.00	11/7/08	11/7/08
Geotechnical studies	**193.00**	**1/7/09**	**10/5/09**
RFP for coring at 4850	0.00	1/7/09	1/7/09
Report after 4850 access	0.00	8/3/09	8/3/09
Report of mapping	0.00	9/3/09	9/3/09
Report after coring	0.00	10/5/09	10/5/09
Excavation Design	**196.00**	**1/30/09**	**10/30/09**
Summary report on global experience in hard rock caverns	0.00	1/30/09	1/30/09
Rock Quality assesment	0.00	9/4/09	9/4/09
Report on Supplementary	0.00	10/7/09	10/7/09



Conclusion

- A 300kT detector at a good depth is well justified for accelerator neutrino physics.
- If built in the USA it has unique and complementary physics capability in the world due the length of the baseline.
- A conventional beam from FNAL to Homestake lab. is going through an examination by a technical working group.
- Excellent sensitivity for θ_{13} and mass ordering and CP violation. Non-accelerator physics additional.
- The caverns built could house different technology: better PMTs, Liquid Scintillator, Liquid Argon ...

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